CLAIMS

WHAT IS CLAIMED IS:

1. A battery monitoring apparatus that obtains a current measurement for a current in a conductive element, the battery monitoring apparatus comprising:

conductive lines configured to couple to a conductive element having an electrical current;

a filter coupled to the conductive lines and configured to filter noise from a signal derived from a voltage difference between the conductive lines, the voltage difference being related to the current in the conductive element;

an analog-to-digital converter that converts the signal filtered by the filter and outputs a digital signal; and

a controller that receives the digital signal from the analog-to-digital converter.

2. The battery monitoring apparatus of claim 1, wherein the conductive element comprises a direct current (DC) shunt.

3. The battery monitoring apparatus of claim 1, further comprising an operational amplifier circuit configured to filter the signal filtered by the filter.

4. The battery monitoring apparatus of claim 3, wherein the filter, the analog-to-digital converter, the controller, and the operational amplifier circuit are located on a current sensing microprocessor card.

5. The battery monitoring apparatus of claim 1, further comprising a thermistor coupled to the conductive element and configured to measure temperature at the conductive element.

6. The battery monitoring apparatus of claim 5, wherein the thermistor provides temperature information used by the controller to compute a temperature correction factor according to the formula:

$$TCF = \frac{R(T)}{R(T_o)} = 1 + TCx(T - T_o)$$

where To is the reference temperature at which calibration is performed, $R(T_o)$ is the resistance at a reference temperature, R(T) is the resistance at a desired temperature, and TC is the temperature coefficient of resistance of the conductive element.

7. The battery monitoring apparatus of claim 1, further comprising a clamp-on meter configured to measure an actual current in a battery.

8. The battery monitoring apparatus of claim 7, wherein the controller receives the actual current measurement and the digital signal representative of a sensed current measurement, and wherein the controller computes a single point correction factor as the actual current measurement over the sensed current measurement.

9. A method for obtaining a current in an activity-based battery monitoring apparatus, the method comprising:

filtering a signal from wires coupled to a conductive element, the signal resulting from a voltage drop across the conductive element;

converting the signal from an analog form to a digital form; and

correcting the digital form of the signal based on temperature at the conductive element storing the digital form of the signal according to the formula:

$$\mathrm{TCF} = \frac{\mathrm{R}(\mathrm{T})}{\mathrm{R}(\mathrm{T}_o)} = 1 + \mathrm{TC}x(\mathrm{T} - \mathrm{T}_o)$$

where To is the reference temperature at which calibration is performed, $R(T_o)$ is the resistance at a reference temperature, R(T) is the resistance at a desired temperature, and TC is the temperature coefficient of resistance of the conductive element.

10. The method of claim 9, further comprising performing a calibration procedure by which a multi-point correction line is computed from an actual current measurement and a sensed current measurement.

11. The method of claim 10, further comprising presenting a user interface to read the sensed current measurement and receive the actual current measurement as an input.

12. A battery monitoring apparatus comprising:

(a) a voltage sense input port to which leads extending to a battery may be connected such that a signal representing the voltage across the battery is provided to the voltage sense input port;

(b) a current sense input port to which leads extending to a universal current measuring apparatus may be connected such that a signal representing the current through the battery is provided to the universal current measuring apparatus, wherein the universal current measuring apparatus comprises a filter to remove noise from received signals, an analog-to-digital converter to convert an analog current signal to a digital signal, and a controller programmed to monitor the digital signal representative of the current to detect a change in battery state

from one of the states of battery charging, discharging, and open circuit to another state, and to define a battery event between changes of state;

(c) an output communications port through which data may be communicated;

(d) a non-volatile memory; and

(e) a programmable microcontroller connected to the voltage sense to receive signals therefrom and connected to the output communications port to at least transmit signals thereto, the microcontroller connected to provide data to and from the non-volatile memory, the microcontroller, to monitor the battery voltage during each event, and to selectively transfer data from the non-volatile memory through the output communications port after a period of time in which events have occurred.

13. The battery monitoring apparatus of claim 12, further including a temperature sense input port coupled to the universal current measuring apparatus to receive a signal therefrom during a battery event.

14. The battery monitoring apparatus of claim 12, wherein the universal current measuring apparatus connected in series with the battery to detect the level and direction of current flowing through the battery, the current sensor including an analog to digital converter to convert the signal corresponding to battery current level and direction to a digital data signal which is connected by a digital data communications link to the current sense input port.

15. The battery monitoring apparatus of claim 14 wherein the universal current measuring apparatus components are mounted on a printed circuit board connected to the shunt, the printed circuit board having a ground plane formed on a first side of the board, and current sense tracks printed on an opposite side of the board which extend from

terminals connected to the shunt to a filter, the filter connected to provide a filtered signal to the amplifier and analog to digital converter on the printed circuit board.

16. The battery monitoring apparatus of claim 14, wherein the universal current measuring apparatus is coupled to a shunt of a known resistance through which flows the current flowing through the battery, an amplifier connected to receive the voltage across the shunt, a filter to low-pass filter the signal from the amplifier, the analog to digital converter connected to receive the filtered output signal from the amplifier and providing a digital output data.

17. The battery monitoring apparatus of claim 16, wherein the universal current measuring apparatus includes a high gain amplifier and a low gain amplifier, each amplifier connected to receive the voltage across the shunt, wherein the analog to digital converter includes a first channel connected to receive a filtered output from the high gain amplifier and a second channel connected to receive a filtered output from the low gain amplifier, the controller programmed to selectively receive the current sense data from the first analog to digital converter channel when the current being sensed is below a threshold value and from the second analog to digital converter channel when the current being sensed is above a threshold value.

18. The battery monitoring apparatus of claim 17, wherein the high gain amplifier saturates at a selected current level and the controller is programmed to select data from the second analog to digital converter channel when the data from the first analog to digital converter channel is at the saturation level of the signal from the high gain amplifier.

19. The battery monitoring apparatus of claim 12, wherein the microcontroller is programmed to store one or more stationary data fields in the non-volatile memory selected from the group consisting of installation time, high voltage setpoint, low voltage setpoint, high current setpoint, high temperature setpoint, battery nominal capacity in ampere hours, battery nominal voltage, a cycle counter, total hours of open circuit overall events, total hours of discharge overall events, total hours of charge overall events, total amp-hours of discharge overall events, total amp-hours of charge overall events, and a count of the number of events recorded.

20. The battery monitoring apparatus of claim 19, wherein the microcontroller is programmed to store all of the stationary data fields from the group of stationary data fields.